Optimizing Scrum Mesoscale Eddy Forecasts

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LONG-TERM GOALS

Our long term technical goal is to produce a tested adjoint for ROMS (the Regional Ocean Modeling System, descended from SCRUM) that is suitable for general use by ROMS modelers. This is complementary to the Kalman Filter, ESSE, and Singular Vector techniques being developed by Rutgers, Harvard and University of Colorado scientists. Our long-term scientific goal is to model and predict the mesoscale circulation and the ecosystem response to physical forcing in the California Current System (especially the CalCOFI region) through ROMS primitive equation modeling/assimilation.

OBJECTIVES

We seek to develop an adjoint model for the Rutgers/UCLA Regional Ocean Modeling System (ROMS) which is a parallel/improved physics descendent of the serial SCRUM (Song and Haidvogel, 1994). We also seek to complete the assimilation system by including the adjoint in an estimation procedure for fitting the model to data. The resulting codes will be suitable for general use in any geometry of ROMS, which presently lacks an adjoint. The adjoint for ROMS will be tested in the California Current CalCOFI region where we are presently applying ROMS (under NASA funding) to a physical-biological data synthesis and a model forecast scenario.

APPROACH

Real-time ocean forecasting involves assembling an initial state which often requires merging many types of data which are usually gathered over non-synoptic timescales. An efficient method for generating a dynamically consistent initial state is the application of the adjoint.

The adjoint is an elegant tool for determining the structure of data sensitivity to model parameters. It can be used to fit an ocean model to observations for use in initializing forecasts and fusing data in hindcasts. The representers, the structure of the sensitivity of a single datum to the model parameters (Bennett, 1992), provide important diagnostics for designing sampling strategies, and for testing model

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predictability limits. We are presently applying a Green's function inverse technique in the CalCOFI domain (funded by NASA) using the ROMS, which is being jointly developed by Rutgers and UCLA. It is of interest to develop the adjoint model to compare it with the Green's function technique and to address model sensitivity to individual data and avoid the complications of finite differencing.

We are developing the ROMS adjoint in collaboration with Dr. Hernan Arango (Rutgers) and Dr. Andrew Moore (University of Colorado) by writing the adjoint by hand since that appears to be the most easily implemented means for reaching the goal in a reasonable amount of time. The final step is to embed the adjoint in an optimization procedure to fit the model to data, using either iterative methods like conjugate gradients or LSQR, or the representer method of Bennett (1992).

At Scripps, co-PI Cornuelle is leading the adjoint development strategy with Ph.D. student Emanuele Di Lorenzo, programmer/analyst Dr. Douglas Neilson and co-PI Miller re-writing and testing the codes. Dr. Hernan Arango of Rutgers is leading the re-design of the code and the adjoint programming strategies in collaboration with Scripps scientists. Dr. Andrew Moore of the University of Colorado is contributing advice on writing adjoint models by hand from the forward model and on testing that is required for assuring accuracy of the adjoint.

WORK COMPLETED

We first attempted to generate the ROMS adjoint using Giering's TAMC but were unsuccessful in developing a feasible plan for using directives to make the TAMC work properly with particular coding structure of ROMS. We then worked with Arango and Moore to outline a strategy for writing the ROMS adjoint by hand. We applied the strategy on test subroutines and are now completing the ROMS adjoint coding.

We also developed an Ocean State Estimate Projects web page to disseminate the results of this project and related projects. The URL is http://ono.ucsd.edu/index.cgi?rsadjoint

We also hosted a workshop at Scripps on "California Current Modeling: Do Observations Corroborate the Modeled Phenomena?". The First Scripps Surfside Climate Workshop brought together scientists who model the California Current System with those who observe the system in order to critically assess the ability of ocean models to simulate the observed synoptic phenomena. Invited presentations were followed by extensive discussions to help identify the major accomplishments, deficiencies and challenges in the present state of California Current modeling (Miller et al., 1999).

RESULTS

During the first year of this project, we familiarized ourselves with the Giering automatic tangent linear and adjoint model compiler (TAMC) and ran some test cases with simple codes. We then invited Dr. Hernan Arango to visit Scripps for a week to assess the usefulness of the TAMC for a ROMS adjoint. During this visit we realized that it would be a difficult task to process the ROMS FORTRAN codes with the TAMC. Parallel loops were not processed correctly by TAMC. The frequent usage of certain constant and scratch arrays in the parallel code was not understood by TAMC. The tracer array in ROMS has five indices t(x,y,z,t,tracer-type); but TAMC was only able to process the array if it is defined without the tracer-type index. In general, it seemed that the structure of the parallel code is not

in the class of codes that the TAMC compiler can process. The serial version of ROMS (SCRUM 4) appeared to be more suitable for TAMC, although after preliminary testing it became clear that major changes to the structure of the code would also be needed in order to make it completely compatible with the TAMC. Some of these difficulties may be solvable by inserting TAMC compiler directives in the code, but this has been made difficult by Giering's move to Germany.

In spring 2000, we invited Hernan Arango and Andy Moore to visit Scripps to initiate a different strategy with the ROMS adjoint model. Sasha Schepetkin (UCLA), Tony Song (JPL) and John Moisan (NASA Wallops) also attended the first-day discussion session on ROMS adjoint development. During the week, we successfully planned out a feasible strategy for developing an adjoint for ROMS. We convinced ourselves that building the adjoint by hand is the best way to proceed. Andy Moore then taught us his clever procedure for writing the adjoint ``by eye" by first writing out line-by-line the Tangent Linear Model and then using that to write out the Adjoint Model. He also outlined vital testing procedures for assuring ourselves that the codes are correct. Our plan now is to distribute the load of writing the Tangent Linear Model and Adjoint Model for each necessary subroutine among all of us using a standard programming procedure. We should soon be able to begin the preliminary steps of testing the codes.

IMPACT/APPLICATIONS

We expect the adjoint for ROMS to prove useful in initializing ocean model hindcasts and determining optimum forcing functions for data fits. We also expect the optimized hindcast simulations to be useful in developing a better understanding of ocean physical processes. We also will be able to use these techniques in a California Current ROMS modeling effort, the results of which can be compared with the application of the Green's function technique developed previously under ONR support (Miller and Cornuelle, 1999).

TRANSITIONS

This work is in the development stage and is not being used by others at this time except through the collaboration with the Rutgers Ocean Modeling Group.

RELATED PROJECTS

We have a project, funded primarily by NASA but also partly by this ONR project, to attempt to optimize predictability of the California Current System in the Southern California Bight (using the CalCOFI CTD data with altimetry, ADCP profiles and surface drifters) using ROMS and Green's function inverse techniques developed under previous ONR support. It will be very useful to compare the results of the adjoint fits with those of the Green's function techniques.

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